DIMORPHISM IN SIZE OF SPERMATOZOA AND ITS RELATION TO THE CHROMOSOMES

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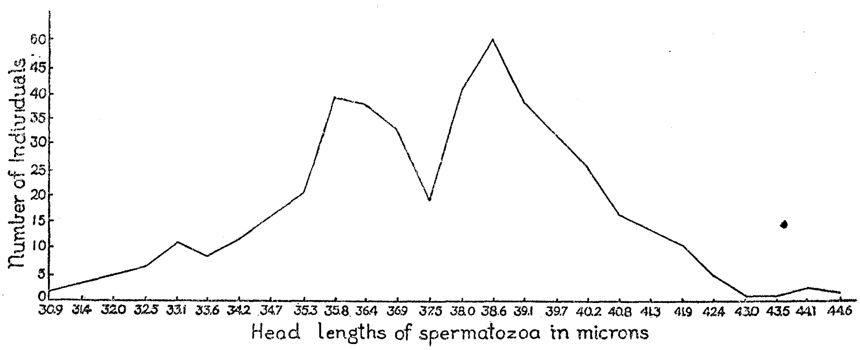
Cytological studies have shown that in the maturation divisions of a large number of species of animals the cells which are to give rise to the spermatozoa are of two kinds, differing from each other in the nature of their chromatin content. The resulting spermatozoa therefore are assumed to be likewise of two kinds. A large mass of indirect evidence makes it highly probable that eggs fertilized by one of these produce only males and those fertilized by the other only females.



EXPLANATION OF FIGURE

Frequency distribution of head-lengths of 444 spermatozoa from right testis of Musca domestica.

Value in microns	30.9	31.4	32.0	32.5	33.1	33.6	34.2	34.7	35.3	35.8	36.4	36.9	37.5
Frequency	1	3	5	6	11	9	12	16	20	39	38	33	20
	38.0	38.6	19.1	39.7	40.2	40.8	41.3	41.9	42.4	43.0	43.5	44.1	44.6
	40	50	39	33	27	17	14	11	5	1	1	2	1

Direct experimental test of this hypothesis has not been made because recognition of the difference has been confined to the immature stages. It is therefore of importance to see if the two kinds can be made out among the completed functional spermatozoa. The present studies were planned with a view to such a determination. If there is a difference in the amount of chromatin received by the two kinds of spermatids it is natural to expect a corresponding difference of size in the heads of the completed spermatozoa since these are made up almost wholly of chromatin material.

The head-lengths of spermatozoa from fifteen species of animals were measured. The number of measurements for a single determination ranged from 322 to 1008 with an average of 523, including in each case only the spermatozoa from a single testis. A considerable variation in length was present and when the frequency distributions were plotted the resultant curves were found to be distinctly bimodal in fourteen of the fifteen species. One of these curves is shown in the accompanying figure. The complete data are summarized in a table. The inference is drawn that there are two groups as regards size among the functional spermatozoa of these species, the group with the larger individuals in each case consisting of those which the studies in spermatogenesis have shown to have the larger chromosomal volumes.

The species for which these determinations have been made belong to several animal groups:

Diptera:	Musca domestica, three determinations.
Heteroptera:	Lygaeus palmii, two determinations.
	Alydus pilosulus, two determinations.
	Anasa tristis, ten determinations.
Coleoptera:	Trirhabda tomentosa, one determination.
	Phytonomus punctatus, two determinations.
Orthoptera:	Melanoplus femur-rubrum, one determination.
	Melanoplus differentialis, three determinations.
	Gryllus abbreviatus, one determination.
Odonata:	Aeshna canadensis, one determination.
Amphibia:	Rana pipiens, one determination.
Reptilia:	Pseudemys troosti, two determinations.
Mammalia:	Ovis aries, one determination.
	Bos taurus, one determination.
	Canis familiaris, one determination.

In all but one of these species two size-groups were recognized. The exception is the one determination of Gryllus abbreviatus. Chromosomal dimorphism has been described for all of the groups except the Amphibia, in most of the cases for the particular species here studied.

A further proof of the close relation between the chromosomal dimorphism of the spermatids and the dimorphism in size of the adult spermatozoa was sought in a determination of the volume of chromosomal material in each of the two kinds of spermatids. From the volumes obtained the expected ratio between the head-lengths of the resultant spermatozoa was calculated under the assumption that the volume of the heads is directly proportional to the amount of the chromatin received and that the shape is the same in the different sizes.

For three of the species studied, Musca domestica, Alydus pilosulus and Anasa tristis, there are good published figures of the chromosomes in the spermatocyte divisions. From these figures it is possible to make a rough estimate of the total chromosomal volume in each of the two kinds of cells. The expected ratio between the head-lengths of the two kinds of resulting spermatozoa was calculated from these data. A close agreement was discovered between the calculated ratios and the observed ratios. For Musca domestica the calculated ratio is 1.00 : 1.08 and the average of the observed ratios 1.00 : 1.07. For Alydus pilosulus these ratios are 1.00 : 1.06 and 1.00 : 1.055. For Anasa tristis the calculated ratio is 1.00 : 1.11 and the average of the observed ratios 1.00 : 1.09 with six of the nine determinations located between 1.00 : 1.10 and 1.00 : 1.12

While there undoubtedly is a considerable error in making minute measurements like those here described and while there may be doubt as to the significance of some of the individual determinations yet the data when taken as a whole must be interpreted as showing the very general existence of dimorphism in size among the completed spermatozoa. The evidence further makes it very probable that this dimorphism is the result of the chromosomal dimorphism present in the spermatids. If this conclusion is a correct one the hypothesis that the chromosomal dimorphism is related to sex determination may be subjected to direct test as soon as a method can be devised for separating the different sizes of living spermatozoa.

TABULATION OF DATA ON HEAD-LENGTHS OF SPERMATOZOA

The observed ratio is the ratio between the two modal values. The expected ratio is calculated from the chromosomal difference between the two kinds of spermatids.

(*over*)

NAME	NUMBER OF SPERMATOZOA	HEAD-LENGTH LOWER MODE IN MICRONS	HEAD-LENGTH UPPER MODE IN MICRONS	OBSERVED RATIO	EXPECTED RATIO
1. Musca domestica	444	35.8	38.6	1.00 : 1.08	1.00 : 1.08
2. Musca domestica	465	35.8	38.6	1.00 : 1.08	1.00 : 1.08
3. Musca domestica	769	36.4	38.0	1.00 : 1.04	1.00 : 1.08
4. Lygaeus turcicus					1.00 : 1.02
5. Lygaeus palmii	493	36.8	38.3	1.00 : 1.04	
6. Lygaeus palmii	501	36.8	37.8	1.00 : 1.03	
7. Alydus pilosulus	429	31.9	33.9	1.00 : 1.06	1.00 : 1.06
8. Alydus pilosulus	469	32.25	33.75	1.00 : 1.05	1.00 : 1.06
9. Anasa tristis	653	28.35	30.2	1.00 : 1.07	1.00 : 1.11
10. Anasa tristis	391	17.5	30.2	1.00 : 1.10	1.00 : 1.11
11. Anasa tristis	370	28.1	30.8	1.00 : 1.10	1.00 : 1.11
12. Anasa tristis	443	17.5	30.8	1.00 : 1.12	1.00 : 1.11
13. Anasa tristis	404	28.1	30.8	1.00 : 1.10	1.00 : 1.11
14. Anasa tristis	384	28.6	30.8	1.00 : 1.08	1.00 : 1.11
15. Anasa tristis	394	28.1	30.8	1.00 : 1.10	1.00 : 1.11
16. Anasa tristis	322	30.8	31.8	1.00 : 1.03	1.00 : 1.11
17. Anasa tristis	993		31.5		1.00 : 1.11
18. Anasa tristis	444	28.4	31.5	1.00 : 0.11	1.00 : 1.11
19. Trirhabda virgata					1.00 : 1.06
20. Trirhabda tomentosa	481	17.02	17.78	1.00 : 1.045	
21. Phytonomus punctatus	506	33.0	34.0	1.00 : 1.03	
22. Phytonomus punctatus	507	33.3	35.3	1.00 : 1.06	
23. Melanoplus femur-rubrum	491	80.5	83.0	1.00 : 1.03	
24. Melanoplus differentialis	481	88.0	90.5	1.00 : 1.03	
25. Melanoplus differentialis	1008	88.8	90.5	1.00 : 1.02	
26. Melanoplus differentialis	734	88.5	90.9	1.00 : 1.03	
27. Gryllus abbreviatus	552				
28. Anax junius					1.00 : 1.07
29. Aeshna canadensis	496	50.2	50.6	1.00 : 1.03	
30. Rana pipiens	494	9.74	10.6	1.00 : 1.09	
31. Pseudemys troosti	501	10.43	10.91	1.00 : 1.05	
32. Pseudemys troosti	487	10.50	11.36	1.00 : 1.08	
33. Ovis aries	498	5.94	6.37	1.00 : 1.07	
34. Bos taurus	606	8.05	8.33	1.00 : 1.035	
35. Canis familiaris	540	5.17	5.55	1.00 : 1.07	